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MORECAMBE BAY

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MORECAMBE BAY RAILWAY

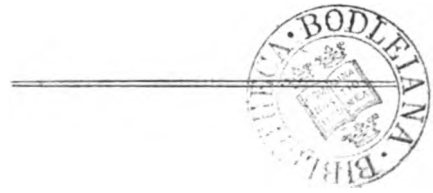
AND

RECLAMATION.

IN 1836 AND 1883.

BY HYDE CLARKE,

CORRESPONDING MEMBER OF THE INSTITUTION OF ENGINEERS OF VIENNA; CORR. MEM. OF THE ROYAL SOCIETY OF NEW SOUTH WALES; CORR. MEM. OF THE ROYAL SOCIETY OF VICTORIA; FELLOW OF THE STATISTICAL SOCIETY; AUTHOR OF "ENGINEERING IN HOLLAND;" "THE HYDRAULIC DRY DOCKS OF THE UNITED STATES;" "RAILWAYS AND COLONISATION IN INDIA," &c.



LONDON.

1884.

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NOTE.

As several applications have been made to me for copies of the papers I read at Southport, before the Mechanical and Statistical Sections of the British Association, in 1883, I have obtained, for private distribution, some copies in separate form from Messrs. Lord and Gill, the proprietors of the newspapers, at Barrow-in-Furness.

The matter was only partially arranged and corrected by me, and contains some verbal errors.

32, St. George's Square, S.W.

January 21st, 1884.

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A Comparison of Morecambe Bay,

BARROW-IN-FURNESS,

North Lancashire, West Cumberland, &c.,

IN 1836 & 1883.

BY HYDE CLARKE, ESQ.

PAPER READ BEFORE THE MECHANICAL SECTION AND THE SECTION FOR ECONOMIC SCIENCE AND STATISTICS OF THE BRITISH ASSOCIATION IN SEPTEMBER, 1883, AT SOUTHPORT.

BARROW-IN-FURNESS:
LORD & GILL, PRINTERS, BOOKBINDERS, &C., "NEWS" OFFICE, PAXTON TERRACE,
1884.

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A Comparison of Morecambe Bay,

BARROW-IN-FURNESS,

North Lancashire, West Cumberland, &c.,

IN 1836 & 1883.

BY HYDE CLARKE, ESQ.

The year 1836 was as is known, a year of great activity in the railway world, and is generally considered as the epoch of the first railway speculation. In fact, a system of railways or tramways was thirty years before conceived, of which the Croyden and the Merstham was a specimen, and the locomotive of Trevithick gave assurance that the lines could be worked by steam. Another railway epoch was that of 1825, when all the great lines were brought before the public, but of which the Stockton and Darlington and the Liverpool and Manchester must be regarded as the chief practical examples.

Still, the great work halted until 1836, and it is a matter for grave reflection among economists and historians that the country, and in reference to what would have been our example, the civilised world, was for thirty years kept back from the realisation of this, one of the mightiest instruments of human progress. The steam engine, of which the locomotive is only a type, naturally attracts first attention, but, in reality, the railway considered even as the offspring of the steam engine, has been mightier than the parent. Natural resources and economy and efficiency of production are of small avail until transport can be provided, whereby commodities can be economically conveyed to markets where they receive a value.

Hence railway development as justly deserves the consideration of the mechanical student, on this ground, as it does on the ground of having given large employment. In 1836, I will remind my contemporaries, that with all George Stevenson and his eminent colleagues had done, we were still in a rude and infant state.

Much was a matter of experiment, and for years we were engaged less in inventions, which of late time have been so remarkable, as in experiments in everything even to the strength and shape of materials, and the railway guage was a great topic of experiment.

To that epoch we owe the more on account of that very condition of circumstances in which experiment is a first step.

My own immediate call to action in that year was in reference to the projected extension of what is now the London and North-Western system from Lancaster to Carlisle. That contemplated what was then, and justly deemed so, the great effort of passing Shap Fell, Westmoreland. The question of gradients then, as always, attracted attention among engineers and the public, and considerable disfavour was expressed, perhaps without sufficient justification, towards the contemplated line over the mountain, then well known in the travelling world.

Into this controversy I, a young man of narrow knowledge, was first privately, and then publicly drawn. The engineers of the Shap Fell plan maintained their project, because geographically it appeared impossible to obtain another route than through the natural pass. Part of my studies had been devoted to the engineering works of Holland, as some may still remember from my treatise on that subject in Weale's Quarterly Papers on Engineering.* To me it may be said naturally to have occurred that the great Bay of Morecambe, so far from offering an obstacle, presented the very opportunity of obtaining a level junction between good gradients in North Lancashire and West Cumberland, and like expedients would carry the line across the Solway, and into Scotland.

Although the idea was in this case absolutely my own, yet as it is said there is nothing new under the sun, so it happened here. Half a century before me and nearly a hundred years before this day, in 1790, Mr. John House-

*Weale's Quatterly Papers in Engineering. Engineering of Holland-Dykes. By Hyde Clarke. (London, 1849.)

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man is related† to have proposed to enclose the Bay, and he then valued the land at £40 per acre. It is also said that Mr. Wilkinson was so satisfied of the undertaking that he was willing to advance £50,000 towards it. This is all the history of the plan which has come in my way, and it appears to have slumbered in local tradition until my proposal revived it, and it was brought in evidence in favour in 1838 and 1839.‡

My originality consisted therefore not in the proposal to embank Morecambe Bay and the Duddon, but, as a means of carrying through arterial communication, and to effect this by employing as capital the value of the land. There were also other details which belonged to me.

Morecambe Bay, within our own neighbourhood, but a few miles off, forms a remarkable indentation among the mountains of the Lake District. It presents what, under other geological conditions, would rapidly have become a plain, and it impeded rather than assisted communication. As the chief part of its large surface is bare at low water, navigation then ceases, and when the tide is up the sandbanks and narrow channels of the rivers give but small facilities. In 1836 the traveller had to creep round the shores of the Bay or to run the hazard of crossing the sands at certain times, in which venture many lives had been lost, as the rising tide sweeps swiftly up.††

Thus, by the geographical impediments of Morecambe Bay, a large north-western district of England was isolated, including the peninsula of Furness and Southern Cumberland. So far as they were concerned facilities of communication ceased at Lancaster. One chief means of access to Furness was by the small port of Ulverston. On the southern shore of the Bay was another unfrequented district of Lancashire, with a fine harbour, the Fylde, now known by the harbour of Fleetwood, with the development of which friends of mine were connected. The Fylde has now been brought within the range of active industry, and has become a practical addition to the resources of the country. For this we are indebted chiefly to three men, Sir Hesketh Fleetwood, Mr. George Walter, also projector of the Greenwich Railway, and Col. Landmann, R.E., the engineer of the railway and harbour.

With regard to Morecambe Bay. the topography of which will be dealt with later, I proposed to cross the estuaries by embankments or dykes. By this means land, dry at low water, was to be reclained, and this was provided as a resource to furnish part of the heavy capital for making a trunk line from Lancaster to Glasgow, through districts then sparse of population, and dependent for obtaining an adequate return on securing possession of the through traffic.

As to the practicability of the plan, bold as it was, there was not much question among those who were brought into practical contact with it. The reason may have been this, that in those days the great hydraulic works of the East of England and of Holland had a greater hold on the memories and thoughts of men, and their influence had not been weakened or effaced by the successes of the railway system. Hydraulic engineering then constituted a great school, in which Mr. Walker and the Rennies, leading men of the day, had earned their distinction. Railway men were only slowly coming to the front.

In Colonel Landmann, an old friend of my father, and who was at work on the Bay at Fleetwood, I obtained a consulting engineer who was staunch to me, and went carefully into every detail of the work. As will be afterwards seen, the plan had a fascination for engineers, and has had godfathers among men of the greatest eminence, until it obtained realisation under the hands of Mr. Brunlees.

The embankment and reclamation were really the main part of the undertaking, and they served to rally to it the leading landowners, whose co-operation ultimately carried it through. It was calculated by me that in Morecambe Bay and the Duddon one twenty-fourth part could be added to the surface of Lancashire. My estimate for the land in Morecambe Bay was 39,210 acres (40,000 acres), and in the Duddon 4,000 acres. The passage of the Solway was contemplated to be by embankment, which would have provided another 20,000 acres or more according to the place of crossing, but this was put forward rather as an alternative. There was soon sufficient knowledge as to the difficulties to be encountered with existing riparian interests, or no interests, even to those who claimed a valueless foreshore, or land to be created, and to which value was to be given by others.

The local knowledge gradually obtained supplied practical confirmation. Thus it came out that on the Ulverston side small patches of sand had from time to time been reclaimed, and some before the beginning of this century. These had stood well, the land was good and rich, and was worth sixty pounds an acre. Many of the doubts which were expressed as to the plan originated in the ignorance of those from whom they emanated; but what was a legitimate matter of doubt, and the solution of which was of importance was whether the sand to be reclaimed was barren or fertile, whether worth nothing or worth something.

To produce so much surface like Dartmoor or Woking Common would not have been worth the labour. At the best, forty thousand acres of Salisbury Plain would only have grazed some sheep. In my own mind there was little room for such doubt, as practical expedients for meeting such a case, and providing suitable soil were suggested by experience. Still, experiment would have been necessary to con-

†Report of Sir H. Le Fleming Senhouse on West Cumberland and Furness Railway in *Whitehaven Herald*, &c., 1838; also MS. report of Hyde Clarke to Local Committee, 1836.

‡It is stated in my MS. report that Mr. Houseman published a work on the topography of this region, p.93.

††See on this subject the valuable archæological paper of Mr. John Fell, Mayor of Barrow, on the Carters of the Sands, hereafter referred to.

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vince the ouside world. It proved, however, from the local tests that good surface soil could be obtained. This confirmed me, too, as to the course to be adopted.

In 1838, my opinions were again quoted in the conditions of the new General Committee. Sir H. L. E. Fleming Senhouse said :—

"On this subject there were some excellent remarks in a work published by Mr. Hyde Clarke, who had surveyed the line, and who had given this opinion on the practicability of crossing the Morecambe Sands.

There are several methods by which a mole or embankment may be carried across the bay. In Holland, most of the dykes are formed of sand faced with reeds or wicker work. In the recent embankment in the Wash, in Lincolnshire, which is similar to Morecambe Bay, the works are formed of clay and sand, and in many parts of the British channel wooden jetties are formed in the sea. With such examples, and a rocky foundation, no doubt can be entertained of the practicability of the measure, and the question resolves itself into one of expense."*

The dykes or embankments were, of course, necessary to carry the railway, and bound the lands to be reclaimed. These were to be protected in case of need by *duin* or other grasses, as at Southport latterly, some of which were known to be effectual for the protection of shores. The construction of the embankments, so far as the land reclamation was concerned was, however, only an independent and necessary preliminary. In Morecambe Bay, the case was very different from the embankment of the Haarlem Meer, the details of which were familiar to me, and also from conference with the engineers concerned. The Haarlem Meer was old inundated land, and during its whole time ot being submerged it had been fed with good soil. Holders partially had shown the agricultural quality of the remainder, as the neighbouring enclosures had tested Morecambe Bay.

My provision included that of warping the sands in Morecambe Bay, leaving them to receive for the necessary time the land deposit from the rivers, and which is one of the most effective processes for such reclamation. The object was to produce good land, and although in the prospectus of the Grand Caledonian Junction Railway the value of the land to be reclaimed was taken at £15 to £20 per acre, no doubt was entertained by those who investigated the subject, that under proper treatment the price realised would be not less than £40 per acre, and possibly £50 or £60 per acre for much of it.

Having devised the plan of railway and embankments, I was actively engaged in its prosecution in 1836 and 1837. I surveyed the line from Lancaster to Dumfries, and made arrangements for the survey of the line from Dumfries to Glasgow by Mr. George Julian, the route proposed by me in Scotland proving the most practicable, being that carried out afterwards as the Glasgow and South-Western. The details of the southern portion of the line were worked out with me by Mr. Richard Julian, assistant engineer of the Preston and Wyre Railway, who became associated with me in the undertaking. Col. Landmann was, as stated, consulting engineer.

As the plans took shape we obtained local support, chiefly from the Cavendish family, through Mr. Joseph Jopling, their agent, and from Col. Braddyll. The towns in West Cumberland gave us a strenuous support. Resolutions in favour were passed by Westmoreland meetings, one in West Cumberland, and by the Burgh of Dumfries, from whom I received thanks. The local press warmed in our cause.

One from whom I received most valuable support was a man locally well-known in his day, Mr. John Rooke, of Akehead, a Cumberland statesman, and an associate of Sir James Graham in economical discussions. Mr. Rooke had begun to apply himself to the geology of the Lake District, and had an intimate knowledge of the topography of our whole line. It may be the more useful to refer to this matter, because in Lonsdale's Cumberland Worthies there is a memoir of John Rooke (with portrait), and it is therein stated that Mr. Rooke employed me, when the relation was the reverse. Dr. Lonsdale promised to rectify this, but he died before a new edition was published.† Mr. Rooke was, however, the projector of a railway since constructed, the Maryport and Carlisle, which became an integral part of the route.

The main spring of our whole undertaking was, as it has been seen, the power of turning to account for its prosecution the development of the land to be reclaimed, and to secure this my energy was greatly devoted. On entering into negotiations with the authorities of the Duchy of Lancaster or the Crown the usual difficulties were encountered. In this case there were not only local but national interests concerned, but the Duchy would give no assistance. It set up a broad claim to all lands to be reclaimed, would afford no contribution towards the work, and, indeed, would enter into no equitable compact. Recent experience has been in the same direction as to Preston, Southport, and Morecambe Bay. The large landowners were willing to come to terms, and their influences, and those of the local communities, were brought to bear in our aid. Crown and Duchy, for we had claimants in both departments, however concurred in this determination, that they would come to no arrangement until the works were completed, when each assumed to be full proprietor of what might be recovered.

* Note: Caledonian. West Cumberland, and Furness Railway.—*Whitehaven Herald, 12th April*, 1838.

†In consequence of his connection with me Mr. Rooke published "Geology as a Science, applied to Engineering, Agriculture," &c. (London Ridgway), which, with other works, was revised by me, though I am not responsible for his theories. He was also a copious writer on economical subjects. He was, as described by Dr. Lonsdale, a remarkable man, and deserving of the esteem accorded to him by Cumberland men.

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This state of affairs was a great impediment and discouragement, but we persevered, because as time went on the great advantages to be obtained were more fully estimated by those resident in these districts.

A committee was formed at Whitehaven to assist in promoting the survey of the Caledonian Junction Railway.

The indirect influence of the movement was, in West Cumberland as in Furness, greater than the direct influence. The West Cumberland Committee for the Caledonian Junction Railway was at Whitehaven, and dissensions sprang up between the supporters of the rival ports of Whitehaven and Maryport. The Maryport people, more energetic than their rivals, determined to have a railway of their own, and they wanted to hold possession of it as a portion of the main line.

In May, 1836, a meeting was held at Carlisle, under the auspices of the then Sir Wilfrid Lawson, Sir Fleming Senhouse, and others, at which it was determined to form the Maryport and Carlisle Railway.‡

In conjunction with the Whitehaven and Maryport Railway a line was thus obtained along the coast, but the connection with the south was not effected until it was accomplished by the efforts of the Furness people.

My own immediate connection with the undertaking was disturbed by the mental alienation of my colleague, and I became a consulting engineer until superseded in the fulness of time by those who were more closely concerned.

My authority in support of the work was however recognised, being supported by every engineer who was called in, and was appealed to on several occasions.

A man who exercised a great influence in succession to me in the promotion of this undertaking was George Stephenson, who, as is well known, took a personal fancy to it, and whose predilection is referred to by more than one writer. Stephenson had been called in by the Cavendish interest.

In 1837, says Mr. Brunlees *(a)* "the late Mr. George Stephenson reported on the practicability of conducting a railway embankment across Morecambe Bay, and at the same time reclaiming from 20,000 to 40,000 acres." George Stephenson's words to Sir H. Le Fleming Senhouse were:—"That feeling not the slightest doubt of the easy practicability of carrying the line across Morecambe Bay, I have no hesitation in expressing a decided conviction of the superiority of the coast line." *(b)*

Mr. Hawkshaw, in the discussion in 1858 on the viaducts of Mr. Brunlees, described the plan as one of some interest, "because it was a favourite scheme of the late Mr. George Stephenson, who entertained the idea of making a railway round Morecambe Bay." *(c)*

‡ *Carlisle Journal*, 21st May, 1839.

(a) Brunlees on sea embankments in Morecambe Bay. P. 3.

(b) Caledonian, West Cumberland, and Furness Railway; *Whitehaven Herald*, 12th April, 1838.

(c) Brunlees on the iron viaducts for the Ulverston and Lancaster Railway. P. 9.

In my "Life of George Stephenson," in the *Civil Engineer and Architects' Journal*, I referred to his having succeeded me in this work. Mr. Samuel Smiles, in his "Life of G. Stephenson," has also spoken of the interest manifested by George Stephenson in the Morecambe Bay work.

Sir H. Le Fleming Senhouse stated—"Mr. Stephenson, as they were aware, had also described his plan of embankment, which was to put in large blocks of stone in consecutive layers, until they formed a complete dyke, up to which the sea was expected to come like a lake, and to fall over in gentle ripples, until the bank silted up inside and became firm and secure." *(d)*

On April 11th, 1838, a large general meeting was held to give new vitality to the undertaking, and my labours were recognised in conjunction with those of its other supporters. The most active advocate of our cause was Sir Humphrey Le Fleming Senhouse. He said:

"Thus had the meeting the opinions of Hyde Clarke, of George Stephenson, of Col. Moody, and of Mr. Hague, in support of the practicabi ity *(e)* of carrying a railway over the Duddon and Morecambe Bay Sands. Mr. Jopling, Lord Burlington's engineer, who is well acquainted with the locality of Morecambe and the Duddon, by a long residence, says:—

"I have not the least doubt that an efficient railway, safe and durable, may be made across Morecambe Bay; and that taking into consideration the land that may be reclaimed, and the greater the quantity reclaimed the less will be the proportional and perhaps actual cost, it cannot be otherwise than an advantageous undertaking." *(f)*

In 1838 the committees were re-organised in West Cumberland and in Furness, and a strong effort was made. Subscriptions were raised not only in these districts, but as far south as Lancaster. Persons in all ranks of life, and particularly the statesmen, subscribed according to his circumstances to the number of 2,000, and each subscriber of £5 was a member of the general committee, of which Sir H. Le Fleming Senhouse was the chairman. In those days railways met with the staunch opposition of the landed interest, but seldom, either then or since, has such a popular movement been set on foot for such a purpose. The people of Dumfries and the City of Glasgow were also aroused.

In the first instance the general committee applied to the Government to appoint an officer of the Royal Engineers to report on the undertaking, as had been done in the case of the Brighton and Dover lines, and also of the Midland. Although a strong plea of public utility was put forward, backed by many peers and members of Parliament, the application was declined, as the previous experiments had

(d) Caledonian, West Cumberland, and Furness Railway.—*Whitehaven Herald*, 12th April, 1838.

(e) The same opinion was manifested at the Southport meetings.

(f) Caledonian, West Cumberland, and Furness Railway, 12th April, 1838.

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not given universal satisfaction. It was expected that Capt. Alderson, R.E., would have been appointed, and he was willing to serve, feeling a special interest which he long maintained in the welfare of the undertaking. Col. Moody wrote:—"I should not so soon have written had I not met with my friend Capt. Alderson, of the Royal Engineers, who being on his way to Spain, was now a disinterested witness, so far as his opinions on future railroads are concerned, at least for some time. I found he had been applying himself to the question of your rival lines in case he should have been called upon, and he had the benefit of much local information from his clerk of the works at Brighton, who is a native of your part of the country, and is personally and well acquainted with Morecambe Bay, Duddon Sands, &c. According to the account which he had received, and those I gave him, he told me as at present informed, he could not have any doubt as to the line which he would prefer, and that would have been the line you recommend. (*g*)

Among the evidence brought forwand at the meeting was that of one largely engaged in hydraulic engineering in the Wash. The following is an extract from the letter from Captain Beazley:—

"My opinion certainly was, when I looked at Morecambe Bay, that it would be very possible to carry a bank across for the proposed railroad, on the principle which I am adopting so far successfully on the Welland, but cannot at present say more from present ignorance of the bay, having only had a casual view of it." (*h*)

Mr. Edward Dawson was also a practical authority of great local influence. Of him Sir H. Senhouse said:—

"Before going further he (Sir Fleming) felt it his duty to state that he had been greatly assisted in his inquiries on the subject of the embankment of Morecambe Bay by Mr. Edward Dawson, of Aldcliffe Hall, near Lancaster, a gentleman of much zeal and perseverance, who had himself embanked a great deal from the sea, and had received the medal of the Society of Arts for the skill and judgment with which the work had been effected. Mr. Dawson was of opinion that the only way of embanking across Morecambe Bay was after the manner in which a portion of the great Wash in Lincolnshire had been recovered—that was by turning the rivers and quietly allowing the sea to deposit the silt thrown up upon it so that in time it would enclose itself." (*i*)

Colonel Moody, R.E., who had been connected with West Cumberland, on being appealed to gave a voluntary report in favour of the undertaking, applying to it the experience he had obtained in the study of the works of Holland. (*j*)

(*g*) Caledonian, West Cumberland, and Furness Railway.—*Whitehaven Herald*, 12th April, 1838.
(*h*) Caledonian, West Cumberland, and Furness Railway.—*Whitehaven Herald*, 12th April, 1838.
(*i*) Caledonian, West Cumberland and Furness Railway—*Whitehaven Herald*, 12th April, 1838.
(*j*) *Whitehaven Herald*, 14th April, 1838.

It was Colonel Moody who introdued Mr. John Hague, and Mr. Hague, as it happened, had some acquaintance with the district, having been there thirty years before, and knowing its general features, was prepared to entertain the project favourably. Mr. Hague was a man then well known in the profession. Colonel Moody said of him:—

"I sent the heads also of your inquiries to Mr. Hague, a civil engineer in London, who had been employed on the dykes against the sea in Holland, under General Blonker, then chief engineer of the water staat department, whom I personally know to be scientifically and well conducted I am sorry I cannot answer your enquiries as to Lincolnshire, but Mr. Hague, who executed extensive works in reclaiming 36,000 acres of land between Lynn and Ely, and embankments, against the sea, with only peat earth and puddling with clay as is done in Holland, has promised me to call on you when he goes to Manchester, and as he also executed works in Holland, he will be able to satisfy you on many points. He perfectly agrees with me as to the practicability of making embankments and a railway on the inner berme in your line." (*k*)

Mr. Hague proceeded to bestow his attention more particularly on the plans for Morecambe Bay and the Duddon. In this he was assisted by men who have since become distinguished in engineering circles, and among them his apprentices Sir Frederick Bramwell, Mr. T. R. Crampton. (*l*)

At this time the undertaking was called the West Cumberland (Furness) and Morecambe Bay Railway. Furness was then conjoined with West Cumberland. To this latter district the prospect of being on a main line communicating by the Maryport and Carlisle Railway with Scotland and with the Newcastle and Carlisle Railway, was a matter of importance. (*m*)

The plans of Mr. Hague became the subject of much local controversy. In the matter of reclamation, however, Mr. Hague, like George Stephenson, fully supported me, for he also reported proposing to reclaim 40,000 acres of land in Morecambe Bay (*n*), Mr. John Urpeth Rastrick having undertaken to act as consulting engineer. Mr. John M. Rastrick was appointed by the committee to survey the railway, apart from Mr. Hague's work, between Lancaster and Maryport, so as to connect with the Maryport and Carlisle line. He reported on the 21st December, 1838, that he had found a line with excellent gradients, and also supported Mr. Hague's plan for embankments (*o*) in Morecambe Bay and the Duddon

(*k*) Caledonian, West Cumberland, and Furness Railway.—*Whitehaven Herald*, 12th April, 1838.
(*l*) When I read this paper before the Mechanical Section of the British Association at Southport, Sir Frederick came forward to state this fact and to give some particulars of Mr. Hague's plans here described.
(*m*) The *Cumberland Pacquet*, a staunch friend of the cause, from 1836 to 1839, said that it would "open out valuable sources of commerce, and population and prosperity" (15th January, 1839).
(*n*) Brunlees, on "Sea Embankments in Morecambe Bay" p. 3.
(*o*) *Whitehaven Herald*, Jan. 1839.

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Mr. John Fowler, afterwards President of the Institute of Civil Engineers, had charge of the survey over Morecambe Bay, and ran the peril of his life on the sands.

It is not necessary to enter at any length into the reports of Mr. Hague and Mr. Rastrick, as to what is of practical interest is found in execution in the works of Mr. Maclean and Mr. Brunlees.

It may be of interest to know what was paid for these surveys. Mr. Hague, who devoted some months to his work, received £30 for his preliminary inspection, and £530 for his final survey, experiments, and report. Capt. Beazley, who rendered some assistance, received about £50. Mr. Rastrick appears to have had about £400.

It has been mentioned by me that one main feature of my plan was the development of the natural harbours of the district and the utilization of their capabilities, more particularly of the Pile of Fouldry. To me this harbour seemed an endowment of nature given to England which was lost and unknown. The whole coast from Liverpool to the Solway was unfavoured. Liverpool itself carries on an enormous commerce under the greatest difficulties. Perhaps it may be mentioned that I laboured for several times to bring into execution a plan which at that time would have greatly assisted Liverpool. There was then a straight channel, probably the remains of a through channel, with good water to Formby Point. A harbour on the Ince Blundell estate, with a short railway branch and a short cut to the canal, would have given an outer port where the tide was an hour earlier and later than at Liverpool docks. Liverpool was well known by me, and so were the Ribble and the Lune. At Fleetwood I had also proposed an improvement.

Nothing in a region reaching to the Scotch coast could compare with the neglected harbour which could float a navy, and from which only some few cargoes of iron ore were casually shipped. The Pile of Fouldry, or Foudry, was better known by the lines relating to it in the Elizabethian poet Drayton *(p)* and its obscure place in mediæval history.

Ulverston appeared to me never to be capable of adequate improvement as a harbour, though with such advantages as a seat of manufacture, for the iron industry of Furness, then at a low ebb, was capable of enormous development. The reason assigned for its retardation in the richness of its ores was evidently insufficient, and would be removed by the application of better economical conditions. Indeed, my advocacy of the great port (now Barrow) injured me with the Ulverston men.

The agitation I created in the Furness district by offering them access as it were to the world, had a great effect in promoting not only the advancement of the Morecambe project, but of all plans for local development. It gave an impulse much needed to local exertion. As the realisation of their hopes in connection with Morecambe Bay were delayed, the Furness people applied themselves to independent efforts. They obtained a better appreciation of their own resources, and a better knowledge of them was acquired by the public. New men engaged in the iron manufacture and the shipments from Foudry or Barrow increased. Mr. Thomas Fisher and Mr. Rawlinson had a great part in this, and Messrs. Schneider and Hannay came in as co-operators.

In 1844, the leading men in Furness, in co-operation with the Earl of Burlington (the Duke of Devonshire) formed a committee to promote a plan for a mineral line from the mines to Barrow. *(q)*

This local line, ultimately carried out, became the centre for communication with the Cumberland railways, the general railway system, and in the end for the main connection which has done most for the district. The line of railway over Morecambe Bay was carried out by a company with Mr. Brogden as chairman, the object being to connect the Furness Railway and the west coast railways with Lancaster and the south. The line was laid out by Messrs. McClean and Stileman, and an Act was obtained in 1851 *(r)*.

Into the detailed history of the Furness Railways it is not necessary to enter, as they do not differ technically from other works of the same kind, while those in Morecambe Bay and the Barrow Docks demand more attention.

The embankment works in Morecambe Bay were described by Mr. Brunlees (now president of the Institution of Civil Engineers) in a paper sent by him to the Institution of Civil Engineers, and to be found in the proceedings for the session 1854-5. This gives all the necessary details from which the account here given is obtained.

Morecambe Bay, it may be stated, is an arm or bay of the Irish Sea, situated to the west of Lancaster. Its average width is about twelve miles, and it extends about seventeen miles inland from the mouth, forming a deep gulf of picturesque character, and surrounded by beautiful scenery. Its dangers were well known to all who travelled over its sands, on account of the constant shifting of the fresh water channels and the treacherous nature of the sands, more especially during freshes in the rivers. This route has, happily, long since been superseded by the railway. A great portion of the bay being left high and dry at low water, its reclamation from the tides was, in the opinion of Mr. Brunlees, a matter of great interest. He acknowledged that it had been the subject of careful inquiry, and that the project had elicited from the most worthy of confidence very favorable recommendations.

The best description of Morecambe Bay and of the rivers Kent and Leven is to be found in

(p) "Barrow-in-Furness: Its Rise and Progress," by Francis Leach, B A., editor of the *Barrow Times*.—Barrow, 1872.

(q) Leach, Barrow-in-Furness. P, 16.

(r) Brunlees on "Sea Embankments in Morecambe Bay." P. 4.

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a paper read before the Archæological Association of the district by Mr. John Fell, J.P., of Dane Ghyll, Furness Abbey, now Mayor of Barrow, and one of the trustees for the office of carters over the two fords. Mr. Fell, besides great local advantages has made an extensive search of the records. These show the constant danger of the passage of the sands for many centuries, and Mr. Fell is, no doubt, right in supposing that the office of Le Carter had reference to the conveyance of passengers over the fords in a cart. The paper is of great interest.

A great portion of Morecambe Bay being left high and dry at low water, as described by Mr. Fell, the mode of passing it by railway became, in the hands of Mr. Brunlees, a matter of careful enquiry (*s*.)

On the existing line of railway over Morecambe Bay the seaworks are very different as carried out by Mr. Brunlees from those originally proposed by myself, and afterwards by George Stephenson, Mr. Hague, and Mr. Walduck, in consequence of the present line being carried more inland than that proposed by me, so that the structures across the estuaries of the Kent and Leven are the principal works exposed to the sea. Although the reclamation of land was a secondary object with Mr. Brunlees in laying out this line, the railway embankments and weirs serve so far to fix the fresh water channels, as to facilitate the reclamation of a considerable portion of the bay, as well as to provide for future development.

The channel of the river was crossed by a viaduct. having 50 spans of 30 feet each. In the viaduct a drawbridge of 36 feet span was afterwards erected, to maintain the navigation of the river. The remainder of this estuary was crossed by embankments formed to the transverse section fig. 2, with a sea slope of 2 to 1, and a land slope of 1¼ to 1.

The embankments from Wyke Marsh, stretching along the shore and across the small bays, to Blawith Point, were formed to the transverse section fig. 3 (in the manner of Mr. Brunlees), with a sea slope of 2 to 1, and a land slope of 1¼ to 1. The embankment was then continued forwards, and completed across that part of Milnthorpe sands to the north of Holme Island, to the point of land where the river Winster had been diverted, and passed under the embankment by a sluice, whence its course is directed to the channel by a stone weir. The line then crosses the Kent estuary at a short distance above its mouth, on ground where the borings showed the bed of sand to have a depth varying from 14 to 21 feet, under which was found a bed of fine blue clay. The River Kent above this point receives the rainfall of the upland districts, from an area of about 110,000 acres. The channel of the river was crossed by a viaduct having 50 spans of 30 feet each, and the remainder of the estuary is crossed by embankments formed to the transverse section fig. 4, with sea slopes of 2 to 1, and land slopes of 1¼ to 1. *(a)*

The sands are, to a great extent, composed of calcareous matter, washed from the limestone of the district, and of this the interior hearting of the banks is almost entirely composed. On the sea slopes, so formed, there was placed a layer 12in. thick of well prepared clay-puddle. In the works in Holland, this is the chief dependence. In Morecambe Bay this clay-puddle serves the twofold purpose of temporarily protecting the material during the formation of the embankment, and of permanently preventing the sand from being washed out from between the joints of the pitching by the action of the sea. On the top of the puddle was laid a thickness of 18 inches of small rubble stones technically termed 'quarry rid,' this prevents the action of the sea upon the puddle. The pitching stones varying from 8 inches to 16 inches in thickness, and of an average depth of 15 inches were compactly set together on this bed of 'rid.' The limestone from the excavations, and the quarries in the immediate vicinity of the works, yielded a very excellent stone for this purpose.

The embankment across the Kent Estuary (fig. 4 in the diagram) differs from the others in the mode of execution. It is found that the sands stand well in still water at a slope of 1¼ to 1; such a quantity of 'rid' was therefore used, under the pitching as to prevent any abrading action of the water, and avert any action upon the sand. When it was consolidated by the passage of the horses and carts in the process of formation, and was set by the rains and spring tides, it was found to resist the passage of the water through the embankment during the flood of the tides.

The heights of the embankments vary with circumstances, the rails on the most exposed parts being 15 feet 6 inches above high water of ordinary spring tides, and 6 feet 3 inches and 4 feet 3 inches respectively, above the extraordinary tide of the 27th December, 1852, the highest tide known in that district. The spray-wall gives an additional height of 2 feet 6 inches above the rails.

Where the sea is cut off entirely by the embankments the land slopes are temporarily protected, during the construction, by a thin layer of puddle, or sods; and where the tide continued to flow up the channels and on the land side of the embankments until the land was fit for reclaiming, the slopes were protected with random pitching, 8 inches deep in the bed.

The sands in the estuaries offer but little resistance to the action of the water in the river channels, especially during floods, spring tides, and high winds. Under these influences, what is locally termed "bracking" takes place, and the channels are frequently re-

(*s*) On the construction of the sea embankments across the estuaries Kent and Leven, in Morecambe Bay, for the Ulverston and Lancaster Railway," by James Brunlees, Mining Institute of Civil Engineers (No. 909)—Proceedings Institution of Civil Engineers, 23rd January, 1855, P. 5.

a) Brunlees on "Sea Embankments," page 4, &c.

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moved, their entire low-water width, displacing during the ebb, upwards of 60,000 tons of sand, within a reach of half-a-mile. This being carried seaward, is to a great extent returned with the flow, and a considerable portion of it is deposited in the former bed of the channel, and on the side opposite to that from which it is removed. Thus the process of excavating from the one side and filling up on the other is constantly going on. The fixing of these channels was therefore a very important feature for the future safety of the works, and for this purpose a weir was formed in the Kent Channel, starting from a projecting point of land and extending parallel with the channel of the stream as far as the site of the intended viaduct, and thence continuing so far seaward as to prevent the channel from turning in and undermining the embankments.

The Leven Channel was also secured in the same way, by a parallel weir, with a landward branch formed of "rid" from the quarry whence many of the pitching stones were obtained. The action of the tides scoured out the sands to a depth of from seven feet to nine feet under low water. This space was made good with stones or "rid" tipped from waggons, thereby giving the work a deep and permanent foundation(*b*). Mr. Brunlees found, in conformity with my original proposition, that in a very short time the sands inland of the weirs were silted up high enough for reclaiming, and these weirs formed the basis of very inexpensive banks for that purpose.

The formation of the embankments in both estuaries had been delayed for some time on account of the shifting of the channels. They were, however, brought so far under the influence of the weirs during the progress of the work that both were led into their permanent positions. The old channel courses silted up.

The railway embankments were formed of the sands taken from the seaward side of them, and owing to the high price of labour during the season of construction two-wheeled carts were used instead of wheelbarrows, and up to 14 feet above the sands no difficulty was experienced in carting. The *modus operandi* was to carry on such lengths as could be raised to a safe height, puddled, and pitched between spring tides, the open end of each being laid to a flat inclination, up which the material for topping was carted. The end was then protected during the springs with clay and stones. In this manner from ten to eleven lineal yards of the embankment were formed per day, or at the rate of a mile in six months, from one face(*c*).

It may be observed that the measures taken by Mr. Brunlees were carefully considered, and founded on experience, and the success of the works during so many years has justified stage by stage the original designs.

The iron viaducts across the estuaries formed by the rivers Leven and Kent were of sufficient interest that they form the subject of a separate memoir communicated by the designer, Mr. Brunlees, to the Institution of Civil Engineers.

These estuaries, where the railway over Morecambe Bay crosses them, are each about 1¼ miles in width. The main bases of the railways were the sea embankments already described (*d*), and the viaducts are the openings necessary for the tidal rivers. The embankments exposed to the sea extend for a length of eight miles.

The superficial stratum of these estuaries is composed of the detritus of calcareous rocks, broken shells, and living molluscs to a depth of 9 feet in the Leven, and 7 feet in the Kent. Below those depths, the strata bear evident marks of a more remote date of deposition, the shells being partly decomposed, and the material assuming a marly appearance. The decomposition increases with the depth, and at a depth of from 50 feet to 70 feet, the material brought up on boring consisted of the finest comminuted dust. When this sand is dry, it is readily driven away by the wind; and when saturated with water the action of treading upon it forms quicksands. The depth of these deposits was not ascertained by Mr. Brunlees, but borings sufficiently numerous and deep were, however, made by him to determine that it was fruitless to seek for a lower foundation, and that in the sands themselves, below the influence of the tides and the rivers, a bearing must be formed for the structures (*e*).

A series of experiments was therefore undertaken to test the bearing power of the sand, and to ascertain the size and form of disk best adapted for a permanent foundation. The experiments were first tried upon a bell-mouthed pile (in plate 10, fig. 1 of Memoir); secondly, upon a bell-mouthed pile with a flat outer rim of metal, and the interior filled and rammed with concrete (fig. 2 of Memoir); thirdly, upon a plain disk pile, open to the extent of the internal diameter and filled and rammed with concrete (fig. 3 of Memoir); and fourthly, upon a plain disk pile, with an orifice of three inches diameter in the centre (fig. 4 of Memoir). Of these forms the last proved the most satisfactory, and it was adopted. The piles with concrete would probably have been equally efficacious, from the tendency of the concrete to consolidate the sand disturbed in sinking them; but from the smallness of the diameter of the piles, there was a difficulty in clearing out the water, and at the same time of introducing the concrete. The experimental piles were sunk from 61 feet to 23 feet in the sand, and were then weighted; the amount of depression being observed for every two tons up to 20 tons. In order to render the conditions of the test analagous to the ultimate duties the piles would have to

(*b*) Brunlees on "Sea Embankments." P. 7 &c.
(*c*) Brunlees on "Sea Embankments in Morecambe Bay.' P. 6, &c.

(*d*) Brunlees on "Sea Embankments in Morecambe Bay.

(*e*) "Description of the Iron Viaducts Erected Across the tidal estuaries of the rivers Leven and Kent, in Morecambe Bay, for the Ulverston and Lancaster Railway," James Brunlees, M. Inst. C. E., No. 978. Proceedings the Institution of Civil Engineers, 20th April, 1858. P. 3.

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perform, the piles were subjected to a constant vibratory motion, simultaneously with the application of the weights. The average result of these experiments proved that the sustaining power of the sand was equal to about five tons per square foot. It being, however, intended that each bearing pile should carry at least 20 tons, the size of the disk was fixed at 2 feet 6 inches diameter, giving an area of 4·86 square feet, or 24·30 tons sustaining power. The disks of the raking piles moreover are made 18 inches in diameter, thus the bearing surface of the disks in the piers consisting of four piles, is 16·30 square feet. As each pier is intimately bound transversely by strong walings and ties, at four different heights, the load is distributed over all the piles, giving a sustaining power of more than 80 tons per pier. In addition to this, the walings have a solid bearing on the weirs of rubblestones, which were introduced to prevent the scour of the channel by strong tides and floods.

With the exception of six piers in the Leven viaduct, where pointed shoe piles are driven into the shingle, and two piers at the end of each viaduct, which are founded on large ashlar stones, the whole of the structures are supported on disk piles. The disks were generally put down twenty feet, and those for the piers of the opening bridges were sunk 26 feet beneath low water. Several arrangements of staging for receiving the piling engine were tried, but such was the shifting nature of the channels in the sands that no staging could be maintained for more than two or three tides. It may be noted as a peculiarity of the water that to have used temporary timber piles would have cost nearly as much per pier, as the permanent piles of iron. It was therefore determined to employ pontoons, and although at the outset much difficulty was experienced in mooring them in the tideway, experience enabled this difficulty to be overcome, and they were ultimately managed and applied with great success. For sinking the disk piles two pontoons were used at each viaduct. Each pontoon was fitted with a small donkey engine of about two h-p., and with a piling machine. The pontoons were moored, on the ebb of the tide, at the site of a pier. The pile was then put into position, and lashed at the top to the slide block in the piling machine, the bottom being "slipped" by the guiding apparatus fixed on the side of the pontoon.

The aperture in the centre of the disk received the lower end of a wrought iron pipe, two inches in diameter, which, extending up the hollow pile, was connected by a flexible hose with the donkey engine and pumps. By these appliances, the water was forced down the pipe into the sand, which, being loosened, the piles rapidly sank. It was found that the piles sank rapidly through the upper or more recent layer of sand, for a depth of from seven feet to nine feet, but that below this depth, in the more compact marly deposit, the progress of sinking was slow. To obviate this obstacle ribs or cutters were cast on the lower surface of the disk, by which, when an alternating rotatory motion was given to the pile, the material was loosened, and was washed or blown away by the water. This plan was found so effective that two piles were generally put down from each pontoon during the ebb of the tide.

In about half-an-hour, after ceasing operations, so much sand had accumulated round the piles as to steady them completely. After the first tide the sand was at its full height, and then the piles were quite stationary. The operation of sinking was much facilitated by keeping a considerable part of the weight of the pile hanging on the piling engine chains. Without this precaution, the piles sometimes sank irregularly and occasionally so fast as to overpower the pumps. To consolidate the sand beneath the disks, which had been disturbed in sinking the piles, each pile was ultimately driven down two inches by short blows from a heavy "tup."

The guide piles, thirty-six in number, forming the approaches to the drawbridge, consist of balks of timber, each 14 inches square, fitted and bolted into cast iron sockets, having a disk 2 feet 6 inches in diameter cast on them (Fig. 5 in memoir). These piles were sunk by the same process, and with as much facility as the hollow iron piles, the water pipe being carried down the outside of the balk and passed through a hole at one side of the disk.

The works for the sea embankments were partially commenced in May, 1853, but owing to the scarcity of workmen, and the want of accommodation for them in the neighbourhood, it was only in September of that year that they were in full operation. The part of the embankment extending along the face of the marshy coast, from Quarry Flat Marsh to Cape's Head, has been formed to the transverse section fig. 1, with a sea slope of 2 to 1, and a land slope of 1½ to 1. The line of embankment then extends directly across the mouth of the Leven estuary, and as in making the borings nothing but sand was found to a depth of 30 feet, and in one instance, where the boring was carried to a depth of 70 feet, the material continued the same, it was necessary to take great precautions for the work, particularly as a large volume of water descends the river channel; the river Leven, above this point, receiving the rainfall from an area of about 109,120 acres, including the drainage of Coniston and the Windermere Lakes.

Such was the simplicity and economy of this mode of sinking hollow piles, that Mr. Brunlees then stated that there could be no doubt of its applicability to the sinking of large cylinders in sand, silt, or gravel, even if the latter contain stones of a considerable size. Experience has confirmed that. The power of the water, by washing aside the smaller stones, would cause the larger ones to fall to the bottom, and thus the process of sinking might be made subservient to obtaining a

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solid and secure foundation. The interior of the cylinders could then be filled up with concrete or masonry in the usual way. This kind of viaduct he recommended as specially applicable for foreign works, all the parts being light and easy of transport, and the skilled labour being performed in this country, except the mere bolting together, the cost would be comparatively small for a permanent structure.

It being thought probable that a double line of way would soon be required, the different parts of the viaducts were originally erected with a view to facilitate the requisite additions. Each ordinary pier consisted, alternately, of four and five piles and columns (figs. 6 and 7 of Memoir). The temporary raking column in every other pier, used as a stay to the single line structure, were, on the widening of the viaducts, put into a vertical position, and became one of the bearing piles, so that only one or two more piles and columns were required in each alternate pier to complete them for a double line.

The piles and columns are 10 inches external, and 8½ inches internal diameter. The longest column above the walings in either viaduct is 22 feet, and according to Hodgkinson's formulæ, deduced from Fairbairn's experiments, the breaking weight was calculated at 408 tons. It was at the time apprehended, erroneously however, that there might be some difficulty in erecting the columns in a perpendicular position; and therefore as the strains were not merely vertical a considerable allowance was made on the actual load to be sustained. On testing one of the columns laid horizontally between two supports 20 feet apart, it broke with a weight of 10 tons in the centre or 20 tons equally distributed, and taking the same length of column in a vertical position the formula gives 480 tons as the breaking weight, or twenty-four times the horizontal breaking weight equally distributed.

The roadways of the viaducts were formed of longitudinal timbers, laid on open planking, 3 inches in thickness, supported by three continuous lattice bearing girders and one light outside girder; so that one line of bearing girders and one of outside girders completed the design for a double line of way. The girders are braced transversely, over each pier, and at three points in each bay. They were made in sheds near the sites, and after being floated to the viaducts on pontoons, were raised and seated by a travelling crane, and were then bolted together, ¼ of an inch was left between the top and bottom plates to allow for expansion, and the holes in the junction plates were made oblong to admit of contraction. The columns were also raised and put into position by the long arm of the travelling crane. *(f)*

Several of these girders were tested in lengths of 30 feet up to a load of 30 tons in the centre, which produced a deflection of half an inch. They were further tested after erection with two engines loaded up to 1¼ tons per lineal foot, and where the girders are continuous no deflection was observable, but the end openings yielded nearly one-eighth of an inch, rising again on the removal of the load.

The piles were effectually defended from the scour of the tides and floods by weirs of rubble stones. These weirs were formed by ordinary waggon roads, from which the rubble was "tipped." The tides kept a scour of from 7 to 9 feet in advance of the "tips," and thus the weirs, being deep seated, and considerably wider than the range of the piles remain quite stationary.

The Leven viaduct consists of forty-eight bays, 30 feet each from centre to centre of the columns, and one bay 36 feet in the clear, for the opening bridge. The height to the rails is 26 feet above low water. In the construction 395 tons of wrought iron and 438 tons of cast iron were used. The length over all is 1,563 feet. The cost, including the stone abutments, the drawbridge with guide fenders and the rubble-stone weirs, was £18,604 for a single line. When completed the cost, for a double line at the same prices, was estimated at £24,361, or £46 15s. per lineal yard. The piling was commenced on the 1st April 1856, and was finished on the 25th October of that year; and the whole erection was completed on the 14th June, 1857. Messrs. W. and J. Galloway, of Manchester, were the contractors.

The Kent Viaduct consists of fifty bays, each 30 feet span from centre to centre of the columns, and one bay 36 feet in the clear as a provision for an opening bridge of the same dimensions as the other. The height of the rails is 23 feet above low water. In the construction 406 tons of wrought iron and 368 tons of cast iron were used. The length over all is 1,566 feet. The cost, including the rubble stone weir and a portion of the provision for a drawbridge, was £15,056, and for a double line was estimated at the same prices at £20,813, or £39 17s. per lineal yard. The piling was commenced on the 21st October, 1856, and was finished on the 31st January, 1857, and the whole structure was completed on 24th July of the latter year. Mr. James Featherstone, of Manchester, was the contractor *(g)*.

The Railway over Morecambe Bay was opened in August, 1857, and it was soon demonstrated by the passage of the ordinary passenger trains and heavy trains laden with minerals and goods that not the slightest depression in the piles was produced, and but little vibration. *(h)*

Proceeding in detail with other subjects the town of Barrow constitutes one prominent feature. The site of Barrow, as seen by me in 1836, had on it an insignificant hamlet. In ten years, in 1847, it had become a village of about 300. This in another ten years, in 1857, had grown to a small town of 2000.

(f) Brunlees on "The Iron Viaducts or the Ulverstone and Lancaster Railway," page 3.

(g) Brunlees on "The Iron Viaducts for the Ulverstone and Lancaster Railway." P. 7.

(h) Brunlee's on "The Iron Viaducts for the Ulverstone and Lancaster Railway," p. 7.

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The following return by Mr. Thomas A. Mercer, Borough Treasurer, in the volume, "Abridgment of Accounts of the Corporation of Barrow-in-Furness, 1882, page 189, shows the successive increase:—

	1867	1872	1877	1882
Population	12,000 ..	18,000 ..	38,000 ..	50,000
Rateable Value ..	£43,534	£76,182	£163,800	£215,000
Mortality per 1000			18·84	18·50

The inventory of this town or city of 50,000 people in the Borough accounts contains some interesting entries. There are enumerated portraits, a statue of Sir James Ramsden, Ramsden Baths presented by Sir James, and numerous town buildings. The amount of the rateable value is, however, one of the best testimonies to the solid character of the progress of Barrow.

In my original report much future impotance was attached to Foudrey (Barrow), and its availability for the Isle of Man and Irish Channel trade pointed out. Of late it has shown its capabilities as an ocean steam port. At that time Fleetwood-on-Wyre, at first called New Liverpool, was but newly founded. Its future growth appeared to me certain, but also that it was incapable of rivalling the opposite port in Foudrey. It presented itself to me as one great advantage of Morecambe Bay in having these two ports, of the present Barrow and Fleetwood, as harbours of refuge and alternate ports to each other. Fleetwood was, however, then capable of much improvement, and I proposed to Colonel Landmann to get a scour by cutting through the neck of the western headland, which would have given greater advantages, but other counsels prevailed, and Fleetwood is relatively dwarfed. A technical description, with plans of the Barrow docks, will be found in the proceedings of the Institution of Mechanical Engineers, August, 1880, as given by Mr. F. G. Styleman, (*i*) who says:—

"As a pupil of the late Mr. J. R. McClean, he was instructed to find his way to Barrow, the means of doing so not being recorded in Bradshaw, and to set out the railway between Barrow and Piel to Dalton and Kirkby. The contract for this portion of the railway was taken by Messrs. John and William Tredwell, in 1844. The line was opened in June, 1846, for the carriage of iron ore and slate, which was shipped from a small T headed wooden pier, erected by the Railway Company at Rabbit Hill Point, about the site of the present Barrow station. At this time the mineral owners would not undertake to guarantee the Railway Company a traffic of 75,000 tons of iron ore per annum, but soon after the opening of the line a great development in the iron ore traffic took place, and this quantity was increased fourfold." (*j*)

"The first harbour authorities (the Barrow Harbour Commissioners) were constituted under the Act of 1848. The powers therein granted becoming inadequate to the rising port, the Commissioners' authority was enlarged in 1855, and became vested in the Furness Railway Company in 1863; and by the same Act power was also given to construct docks. The construction of the docks then authorised, situate between Barrow and Barrow Island, was let in 1865 to Messrs. Brassey and Field. The docks have been named after the two Dukes, Devonshire and Buccleuch, the chairman and deputy chairman of the Furness Railway; and were formally opened on the 19th September, 1867, with great public enthusiasm." (*k*)

Sir James Ramsden, at the same meeting of the institution, said: "With regard to the question of silting, the water in Barrow harbour was all pure sea water; there was no alluvial deposit, and consequently no silt. The bottom of the channel was hard material, gravel and clay. Moreover the island of Walney gave a double entrance both north and south; and it was a curious fact that, owing to the meeting of the waters of the Atlantic and the Irish Channel immediately opposite Morecambe Bay, the level of the tide at Piel was two feet higher than it was at the estuary of the Duddon, nine miles further north. Hence for two hours after high water the tide was running to the north, and when the water returned it was as clear as crystal, so that any mud moved by the flowing tide was washed away into the sea to the north. The dredging work had been very much facilitated by the scouring power of the tide. All that the dredgers had done had been to remove the hard clay and gravel, the tide washing away the finer material. He believed that two-thirds of the material removed had been washed away by the operation of the tide.

The Barrow docks have all needful appliances. Their crane will lift 100 tons, and they have, besides a 30-ton crane, a large number of ordinary fixed hydraulic and steam cranes. The two large railway bridges across the dock open by hydraulic power, as also do the dock gates.

What the dock authorities look upon as a speciality is a Depositing Dock for the repair of ships. This is stated, by Mr. Cook, to be the only one as yet in England, and was constructed by Messrs. Clark and Standfield, on their patent, and is described in *Engineering* of 8th July, 1881 (*l*).

Mr. John Fell, the Mayor of Barrow, has given me much valuable information on the docks and trade of that important town, more in fact than can be here applied. The Borough Treasurer, Mr. Mercer, the Town Clerk, and Mr. H. Cook, of the Furness Railways, have co-operated in this respect with Mr. Fell, and Sir James Ramsden, one of the founders of the town, has also contributed in aid of my inquiries.

The following is a return of the work of the Barrow Harbour and Docks from the year 1878 to 1882, communicated to me by Mr. H. Cook:

(*i*) On the Docks and Railway Approaches at Barrow-in-Furness. By Mr. F. C. Stileman, p. 324.
(*j*) "On the Docks at Barrow-in-Furness," by Mr. F. C Stileman. P. 325.
(*k*) "On the Docks at Barrow-in-Furness." P. 333.
(*l*) In Weale's Quarterly Papers on Engineering will be found the earliest description by me of this class of dock, entitled "The Hydraulic Dry Docks of the United States.

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BARROW HARBOUR AND DOCKS, 1878—1882.

Year.	No. of vessels entering Harbour.	Registered Tonnage.	Export Cargoes.						Import Cargoes.								Total exports and imports.	No. of head of Live Stock (exclusive of geese) imported.
			Iron ore.	Pig iron.	Steel rails.	Other cargoes	Total exports		Timber	Gra'n and Flour	Coal.	Iron ore.	Iron and steel.	Other cargoes	Total imp'rts.			
			Tons.	Tons.	Tons.	Tons.	Tons.		Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.		Tons.	No.
1878	1500	372829	25370	140785	44233	68770	281218		94728	18259	21348	51042	7281	57497	250155		531373	41781
1879	1428	386374	33666	192406	65319	53612	345003		62836	28886	14686	32184	319	52701	191612		536615	31394
1880	1947	539519	56220	258102	68581	78515	461418		106353	26993	15342	86416	12824	66010	313938		775356	39649
1881	1826	507877	75350	171303	94183	76147	416983		87686	37030	18665	37878	9326	74997	265582		682565	24118
1882	2123	539455	71458	202890	95830	92573	463751		111994	20776	20848	41748	12146	79773	287285		750036	33240

A very good description of the mineral geology of the Furness district will be found in a paper by Mr. J. L. Shaw, of Barrow, in the proceedings of the Institution of Mechanical Engineers for 1880. The title is "On the Hematite Iron Mines of the Furness District." It is illustrated with a map and diagram. (*n*).

In the discussion on Mr. Shaw's paper, "Mr. Edward Wadham said it might be interesting to the members to learn a little as to the uncertainty of working iron mines in the Furness district. Of all the mineral deposits with which mining engineers had to deal, there was nothing so uncertain as hematite iron ore. As described in the paper, it lay in joints and fissures of the limestone rock, and at the divisions between the limestone and the clay slate rock below and between the limestone and the new red sandstone above. As shown by the diagrams, the method of working was necessarily very irregular." (*o*).

Mr. Wadham stated that in the Furness district it was found all mineral veins took more or less the direction of north and south, but the hematite iron ore was in no way magnetic, (*p*)

The following is a comparative return of the make of pig iron and steel in the ten-yearly period of 1872 and 1882, for the Barrow Hematite Iron and Steel Company, contributed by Mr. Fell:—

MAKE OF PIG IRON AND STEEL OF THE BARROW HEMATITE STEEL COMPANY.

Pig Iron.

	Tons.	Men.	Steel.	Men.
1872	223,223 ..	659 ..	94,473 ..	1,631
1882	328,472 ..	705 ..	191,460 ..	1,482

HEMATITE ORE RAISED BY THIS COMPANY.

	Tons.	Men.
1872.....	309,796 ..	782
1882.....	522,910 ..	1,409

A most important feature in connection with this subject is the enlargement of the resources of the Furness district by the discovery of new mines, which have made it independent of foreign supplies of mineral. (*m*).

In the past, Barrow has been one of the great examples of the energy of our people, and with Middlesbrough on the other side of the island, it shows that we in the old country can exhibit towns, the growth of which is as remarkable as those in the new worlds of America and Australia.

The future of Barrow must be a great one in consequence of its geographical advantages, if but due care be employed to turn them to account. Through competition, the iron trade may be subjected to vicissitudes, and coal may not be found in Furness, but a straight line across the Duddon will bring in the West Cumberland coal so as to supply other manufactures and shipping.

It is possible to contemplate a population of one hundred thousand or of two hundred thousand occupying the town and engaged in the development of its resources.

With regard to the estuary which closes the peninsula of Furness to the north and west, the Duddon, a smaller and shallower sheet of water than Morecambe Bay, its passage and reclamation were also proposed by me; but it is a matter of much minor importance than Morecambe Bay, though by no means to be neglected, and which it is to be hoped will now be taken in hand.

In the future of Morecambe Bay, the passage and reclamation will be accomplished fully but most possibly not on the line pro-

(*n*) On the Hematite Iron Mines of the Furness district, by Mr. J. L. Shaw, of Dalton-in-Furness. Page 369.

(*o*) On the Hematite Iron Mines, p. 371.

(*p*) Report of Hyde Clarke on Grand Caledonian Railway, 1836.

(*m*) As my attention had been already directed to metallurgic studies my contact with the Furness district led me to take a more active interest. In time this led me to copper smelting, and to the publication of papers on copper smelting (Society of Arts Journal 1854, and elsewhere)

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posed by me, because as Barrow has now risen to importance, and will rise further, the provision of railway accommodation for it governs the future course. If, as appears most possible, a direct line such as that proposed by Mr. Walduck shall be carried across Morecambe Bay, then it follows that Barrow will require further a more direct line to the west coast of Cumberland.

Taking up the description of the Duddon river, it is at its entrance above three miles wide, but this space is so filled up with sands that it is only navigable by small craft, having not more than seven or eight feet over most of the banks at high water spring tides, and with neap tides only two or three feet. Its channels are circuitous and narrow.

Of the justice of these first and early plans and estimates sufficient confirmation has since been obtained. Not to speak here of what, as a pioneer, though on a small scale, Mr. Brunlees has done, the Warton Land Company is engaged in reclaiming 7,000 acres of land on the Lancaster side of the Bay, and arrangements have been made with the Crown authorities for a further reclamation in the middle of the Bay of 11,000 acres.

The Warton Land Company, like the other undertaking, is due to the enterprise of Mr. H. J. Walduck, of Silverdale, Carnforth. It provides a seawall which by a sweep is to enclose the east side of Morecambe Bay in the estuary of the Kent, and in the neighbourhood of the town of Lancaster. This concession is held under a grant from the Duchy of Lancaster, and by arrangements made under the Act of Incorporation.

The engineers of the Warton Land Company are Messrs. Brunlees and Mr. Kerrow, and considerable sums have been spent on the works, and sufficient has been done to show that the works and undertaking are thoroughly practicable. Although the works have not been conducted with energy they have been attended with this curious feature, that although stopped at the end of 1879, when the land was left at a certain level, it has still further silted up, showing a large accretion of soil without further expenditure of labour. An area of some 3000 acres has thus been raised.

Among the successful reclamations of late years should be reckoned that effected by Mr. Brogden, M P., at Meathorp, which has been valued at £60 to £70 per acre.

Here, perhaps, may be noted the experiment of an early friend of the undertaking, Mr. Stockdale, of Cark, as related by Sir Frederick Bramwell. Mr. Stockdale, during the survey to show what the soil was, sank a cart in the sands, planted potatoes, and in time sent the crop to be shown in London. The land reclaimed by the Railway Company at Winster Bay and at Holker is reckoned to be of the same value.

The Cartmel Wharf reclamation of Mr. Walduck, which the Duchy of Lancaster authorities are prepared to approve, proposes, as stated, to deal with the main body of the sands in the centre of Morecambe Bay.

This plan, however, is connected with a design of Mr. Walduck for the Hest Bank and Barrow District Railway (Morecambe Bay Railway.) He proposes to start from the same spot on the Lancaster or east side at Hest Bank, that I did, and he follows much the same line to the west side of the Bay. For the purposes of the through traffic I bore more upon Dalton, but Mr. Walduck wishes to strike the shore a little more south, so as to be nearer to Barrow-in-Furness, and to give it a direct railway communication.

At the mouths of the Leven and the Kent he provides wide viaducts, but the ultimate fate of these estuaries must be to be warped or silted, leaving only the river channels. By this route Mr. Walduck calculates that the distance to Barrow from Hest Bank to Barrow will be shortened from 34 miles to 17, a most material saving for passengers to that town. The whole line will naturally be on a level,

The Warton Land and Cartmel Wharf undertakings, severally of 7,000 acres and of 11,000, constitute a total reclamation of 18,000 acres, a most important work in reference to the extension of the material resources of the country.

My original undertaking embraced a level main line for the north-west of England, providing a through line to Glasgow, with a branch to Edinburgh, under the name of the Grand Caledonian Junction Railway.

At that time the railway system was in its infancy in West Cumberland. One of my especial aims was to develope the coal and iron mines of that region, then in their infancy, but of which the value was evident to me, when an outlet could be obtained for them in addition to the ports of Whitehaven, Maryport, and Workington, then chiefly supplying the Irish markets. The accommodation of those harbours was so limited, access to the great port now known as Barrow appeared to present great advantages.

At first I had contemplated dealing with the small estuary of the Wampool and the Waver, on the south shore of the Solway, so as to get across the great frith to the west, and obtain a shorter line into Scotland, with a larger extent of reclamations. The examination of the channels of the Wampool and Waver was, however, very unfavourable, and I was induced to propose a crossing of the Solway higher up. It is by no means certain that my determination, although then expedient was without objections. At some after time, under more favourable auspices, the Solway may be advantageously crossed. At that time no one dared to contemplate such works as those over the Forth and the Tay.

My plan included a branch to Carlisle so as to connect with the Newcastle and Carlisle Railway.

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With regard to the Solway, I should certainly have preferred an embankment with provision for navigation to Carlisle, in fact, the same kind of work as Mr. Brunlees afterwards executed in Moremambe Bay. The ultimate extent of land to be reclaimed was at least 8,000 acres.

The line I proposed for Scotland from the Solway to Dumfries and then by Lanark and Hamilton to Glasgow was much the same as that subsequently carried out as the Glasgow and South-Western Railway, and that for a sufficient reason, that it was the best route that the natural configuration of the country allowed. From Dumfries to Glasgow the line was not surveyed by myself, but the survey followed the course which I had indicated from the best examination I could make.

My plans also included a junction with Edinburgh, and a branch to Portpatrick for Ireland, both of which have been accomplished.

Among obligations to many who have assisted me in this paper, I must not omit Mr. James Forrest, secretary of the Institution of Civil Engineers, whose wide knowledge and readiness to impart it, have made myself and others debtors to him.

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